PROGRAM PLAN FOR CONTROL ROOM DESIGN REVIEWS

FOR ALL TVA NUCLEAR PLANTS

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ABBREVIATIONS

ACR - Auxiliary Control Room
BISI - Bypassed and Inoperable Status Indication
BWR - Boiling Water Reactor
CR - Control Room
CRDR - Control Room Design Review
DCRDR - Detailed Control Room Design Review
EN DES - Division of Engineering Design
EOF - Emergency Operations Facility
EOP - Emergency Operating Procedure
EPG - Emergency Procedure Guideline
EPRI - Electric Power Research Institute
ERF - Emergency Response Facility
HE - Human Engineering (Same as HFE)
HEC - Human Engineering Concern
HED - Human Engineering Discrepancy
HFE - Human Factors Engineering (Same as HE)
INPO - Institute of Nuclear Power Operations
I&C - Instrumentation and Controls
LER - Licensee Event Report
MCR - Main Control Room
NRC - Nuclear Regulatory Commission
NSSS - Nuclear Steam Supply System
NTOL - Near-Term Operating License
R.G. - Regulatory Guide (NRC)
RO - Reactor Operator
SPDS - Safety Parameter Display System
SRO - Senior Reactor Operator
TMI - Three Mile Island
USQD - Unreviewed Safety Question Determination
V&V - Validation and Verification

1.0 INTRODUCTION

1.1 Purpose. This program plan describes a plan that presents the main elements of the human engineering (HE) efforts to identify and correct deficiencies in design and operation of TVA nuclear power plants. Guidance is provided to TVA personnel having responsibilities for planning, conducting, and reporting detailed control room design reviews (DCRDRs), and for recommending appropriate follow-up corrective actions related to the human engineering discrepancies (HED) revealed in the DCRDR. The program plan also serves to ensure compliance with pertinent Nuclear Regulatory Commission (NRC) directives and guides.

1.2 Scope. The program plan presents:

a. Methodology for the phases of the DCRDR efforts - planning, conducting, assessing and implementing, and reporting.

b. Structure and management of the DCRDR team.

c. As appendixes, selected resources for use by DCRDR team personnel during the phases of the program.

1.3 General. The focus of the program plan is that the reactor operators (working at the man-machine interfaces in the plant) are significant factors of safe and productive nuclear power plant operations.

This program plan addresses the man-machine interfaces of the main control room (MCR) and the auxiliary control room (ACR) only and equipment required to transfer control to the ACR.

Human factors engineering (HFE) principles are incorporated in the program plan.

1.4 Definition of the Physical Review Area. The physical area for CRDR activities will be as shown in Figures 2, 3, 4, 5 and 6 and will include all of the illustrated control panels. Also included in the review will be the auxiliary shutdown panels at the respective nuclear plants.

2.0 APPLICABILITY

This program plan is applicable to TVA nuclear power plants up to and including the Bellefonte Nuclear Power Plant. In addition, TVA has worked with the Boiling Water Reactor (BWR) Owners' Group to perform a CRDR at Browns Ferry Nuclear Plant and with the NRC during the preliminary design reviews for the Sequoyah and Watts Bar Nuclear Plants. TVA intends to use as much of those efforts as possible for

completing the CRDR activities at Sequoyah and Watts Bar. TVA considers the activities performed by the BWR Owners' Group as sufficient for meeting the requirements of this program plan for the Browns Ferry unit control rooms, with the exception of completing subsections 6.6 (Task Analysis) and 6.7 (Additional Analysis).

3.0 DEFINITIONS

3.1 Function (Subfunction). A kind of activity (or a static role) performed by one or more system constituents (people, mechanisms, structures) to contribute to a larger activity or goal state.

3.2 Function/Functional Analysis. The examination of system goals to determine what functions they require. Also, examination of the required functions with respect to available manpower, technology, and other resources, to determine how the functions may be allocated and executed.

3.3 Function Allocation. The distribution of functions among the human and automated constituents of a system.

3.4 Human Engineering. The science of optimizing the performance of human beings, especially in industry. More narrowly, the science of design of equipment for efficient use by human beings (also known as bioengineering, biotechnology, engineering psychology, ergonomics, and human factors engineering).

3.5 Human Engineering Concern (HEC). An item designated by a CRDR team member as a potential HED.

3.6 Human Engineering Discrepancy (HED). A characteristic of the existing control room that does not comply with the human engineering criteria used in the control room survey.

3.7 System (Subsystem). An organization of interdependent human-equipment constituents that work together in a patterned manner to accomplish some purpose.

3.8 System Function Analysis. The determination of system functions required to meet system goals.

3.9 Task (Subtask). A specific action, performed by a single system constituent, person or equipment, that contributes to the accomplishment of a function.

3.10 Task Analysis. A procedure used to delineate which specific actions must take place to accomplish system functions. In the CRDR context, task analysis is used to determine the individual tasks that must be completed to allow an emergency system to function properly. This verification activity checks the control room match to the emergency operating procedures.

3.11 Validation. The process of determining whether the control room operating crew can effectively perform their functions given the control room instrumentation and controls, procedures, and training. In the CRDR context, validation implies a dynamic performance evaluation.

3.12 Verification. The process of determining whether instrumentation, controls, and other equipment are available to meet the specific requirements of the emergency tasks performed by operators. The control room survey and task analysis are verification activities, checking the control room match to the human operator.

3.13 Line Organization. The TVA division assigned full authority and accountability for a given plant (e.g., EN DES Bellefonte Design Project is the line organization for Bellefonte Nuclear Plant and NU PR is the line organization for Browns Ferry Nuclear Plant).

4.0 COORDINATION AND INTEGRATION WITH RELATED EFFORTS

4.1 Related Efforts. The control room design review (CRDR) process proceeds simultaneously with a number of other related efforts, including:

a. Provision of the following new instrumentation and facilities:

(1) Safety parameter display system (SPDS).

(2) Emergency response facilities (ERF).

(3) Post-accident monitoring instrumentation (reference II.3.9).

(4) Bypassed and inoperable status indication (BISI) system.

b. Updating emergency operating procedures (EOP).

c. Changes in requirements for training and staffing.

4.2 Major Tasks. The CRDR will be integrated with the above related efforts. There are basically seven major tasks associated with the CRDR:

a. Develop CRDR Program Plan.

b. Survey MCR and ACR.

c. Perform Operator Experience Review.

d. Perform Task Analysis.

e. Assess HECs for Possible Redesignation as HEDs.

f. Assess HEDs.

g. Develop Recommendations for Corrective Action.

The functional relationships of these tasks are directly tied to other initiatives which may be completed prior to completion of the CRDR.

5.0 STRUCTURE AND MANAGEMENT OF CRDR TEAMS

5.1 Team Composition. The CRDR is a large project that will be conducted on operating plants (without interrupting operation) and on plants preparing for licensing. People with various types of training and experience are needed to perform the required tasks, so a multidiscipline core review team consisting of an even mix of members from the design and operating organizations in TVA will be used to provide the basic technical knowledge. The core review team will consist of:

a. Instrumentation and Controls (I&C) Process Engineers (approximately three I&C process engineers to represent the various internal TVA organizations)

b. Human Factors Specialists

c. Nuclear Engineers

d. Reactor Operators

Expertise not provided by the core review team will be met by bringing in specialists to perform the desired tasks, e.g., systems engineer--sound/noise, HVAC, lighting measurements. The qualifications used to select review team personnel are as follows:

Human Factors Specialist.

The human factors specialist is required to have a degree, preferably at the graduate level, in one of the disciplines recognized as related to human factors, including but not limited to: anthropology, anthropometry, bio-engineering, ergonomics (HFE), industrial engineering or design, medical electronics, medicine, psychology, quantitative methods. In addition, the person is required to have a minimum of five years of experience in the application of HFE.

Reactor Operator (RO). For TVA's operating plants, a licensed RO, preferably in the specific control room being reviewed, will be selected. For near-term operating license (NTOL) facilities, a licensed RO of that plant or a licensed RO with two years of operating experience in a control room similar to the one being reviewed, will be selected.

Instrumentation and Controls (I&C) Engineer. A bachelor's degree in engineering and a minimum of three years of applied experience in the nuclear field is required. The I&C process engineer must be familiar with the regulations, standards, and design constraints that have an impact on nuclear power plant control room design.

Nuclear Engineer. A bachelor's degree in engineering and a minimum of three years of applied experience in the nuclear field or shift technical advisor training is required. This individual will be used extensively to review system functions and analyze operator tasks.

5.2 CRDR Team Management. The guidance, direction, and activities of CRDR preparation are outlined in Figure 1. The structure of the review team will vary for the different CRDR efforts because of the needs, capabilities, and resources available. It is TVA's approach that in-house personnel will be used to perform the review. To administer and coordinate the CRDR activities, TVA will assign management grade employees from design and operations organizations to serve as the focal points for all CRDRs within TVA. These managers will share the following responsibilities:

a. Develop the program plan report.

b. Develop and assign tasks for the various review teams.

c. Develop a schedule for the CRDRs and determine appropriate milestone checkpoints.

d. Integrate the CRDRs with other activities which may impact the control room (e.g., EOPs, SPDS, R.G. 1.97).

e. Provide the coordination required to ensure that all internal TVA organizations are kept abreast of the review teams' efforts.

f. Ensure that management attention is provided to all tasks within the HFE framework.

g. Provide technical guidance and support to the various review teams.

h. Coordinate the final report for the CRDRs.

5.3 Review Team Technical Leader. Since TVA will have three nuclear plant review teams (one team for Browns Ferry, Sequoyah and Watts Bar, and Bellefonte), an individual will be assigned as project specific review team technical leader who will coordinate his review team activities with the CRDR team management. The responsibilities assigned to the project specific review team technical leader are as follows:

a. Coordinate review team activities with all core review team members.

b. Perform the requirements of the CRDR delineated in subsection 6.3.

c. Work closely with the CRDR team management to ensure schedule milestones are met.

d. Maintain all related documents needed by the review team (e.g., Final Safety Analysis Report [FSAR], instrument tab).

e. Participate in all review team activities and coordinate the project specific final report.

f. Perform as team spokesman and meeting chairman for all review team activities.

5.4 Review Team Responsibilities. The different phases of the CRDR will require varying degrees of emphasis of the primary disciplines but, in order to function well as a team, all team members will participate in most team activities.

Even though the project specific team technical leader has overall responsibility for the assigned tasks, Table 1 defines the recommended disciplines which will be emphasized to provide appropriate technical direction to those efforts.

Table 1. Discipline Emphasis in Review Process

Review Process	Discipline Emphasis
1. Operating Experience Review:	
a. Examination of Pertinent Documents	Nuclear Systems Engineering/ Instrumentation and Control
b. Control Room Operations Personnel Survey	Human Factors
2. Review of System Functions and Analysis of Operator Tasks:	
a. Function Identification	Nuclear Systems Engineering
b. Function Analysis	Human Factors
c. Operator Task Identification	Nuclear Systems Engineering/ Reactor Operations
d. Task Analysis	Human Factors
3. Control Room Survey	Human Factors
4. Verification of Task Performance Capabilities:	
a. Verification of Availability	Instrumentation and Control/ Reactor Operations
b. Verification of Human Engineering Suitability	Human Factors
5. Validation of Control Room Functions	Instrumentation and Control/ Reactor Operations/Human Factors

Specifying a discipline which should be emphasized for the various review processes does not imply that these functions should be performed solely by the team members with that expertise. All of the disciplines and types of experience represented on the CRDR review team will be necessary for most efforts in the review.

5.5 Responsibilities of CRDR Team Members. Individual CRDR team members will:

a. Participate in team planning sessions (see Figure 1).

b. Assist the CRDR team technical leader and other team members in areas of expertise.

c. Participate onsite in the conduct of the scheduled CRDR.

d. Document CRDR findings, assessments and recommendations, and present them to the CRDR team technical leader.

e. Document individual dissenting CRDR opinions, findings, assessments, or recommendations, and present them to the CRDR team technical leader.

f. Participate with the CRDR coordinator and other team members in preparing preliminary and final CRDR reports.

6.0 PREPARATION OF CONTROL ROOM DESIGN REVIEWS

6.1 Human Engineering (HE) Principles. HE principles are compiled in a number of governmental, professional, engineering, and scientific sources and documents. CRDR team members should be aware of the following HFE resources:

a. TVA EN DES Design Guides E18.1.11, 12, 13, 14, and 15 (references 11.2.1 through 11.2.5). These documents combine HE principles and proven TVA engineering practices.

b. Electric Power Research Institute (EPRI) Reports (references 11.1.1 through 11.1.6). These reports address HE topics, problems, and HEDs generic to the industry. The NP-1118 series of reports are landmark documents of HE analyses of nuclear control room design.

c. Human Factors Design Handbook (Woodson, reference 11.4.5). This document contains information on optimum design practices derived over many years from many disciplines, including engineering design, medicine, physiology, anthropology, biology, personal hygiene, and psychology.

d. Human Factors in Engineering and Design (McCormick and Sanders, reference 11.4.4). This fifth edition of an early landmark in the field is a survey treatment of topics pertinent to CRDRs, including information input, human output and control, workspace arrangement, and environment.

e. Human Engineering Guide to Equipment Design (Van Cott and Kinkade, editors, reference 11.3.1). A basic document on HE, it is a combined effort of governmental, university, and private sector HE scientists, engineers, and researchers.

f. MIL-STD 1472 (reference 11.3.2). The U. S. Department of Defense, through its several HE laboratories a principal user and beneficiary of HE research, in this military standard presents HF design criteria, principles and practices for application in the design of system equipment and facilities. Prepared for use by the U.S. military, it is in large measure applicable for CRDR use.

g. NRC NUREG 0700 (reference 11.3.3). This document provides the guidance that the NRC staff believes should be followed to accomplish the CRDR. Much of its guidance is derived from basic HE documents as they pertain to nuclear power plant MCR design.

h. Appendix A. Appendix A is a comprehensive compilation of HE principles in the form of checklists.

i. Appendix B. Appendix B, "Human Factors Review Team Guidelines," is a concise, systems-oriented compilation of HE principles pertinent to nuclear power plant MCR operations. They are apropos preparation for, and conduct of a CRDR. The source is reference 11.4.3.

j. The documents produced by the Nuclear Utility Task Action Committee (NUTAC) on CRDR.

6.2 Associated Disciplines. In addition to their awareness of HE, individual members of a multidiscipline DCRDR team are required to be fully qualified in one or more of the following disciplines: instrument and control engineering, nuclear engineering, nuclear plant operations, or HFE.

6.3 Requirements. Under guidance of NUREG 0737, Supplement 1 (reference 11.3.8), NUREGs 0700 (reference 11.3.3), 0737 (reference 11.3.4), and 0801 (reference 11.3.6), the CRDR requirements are:

a. Conduct a CRDR as follows:

(1) Establish a qualified multidiscipline review team.

(2) Perform a review of operating experience.

(3) Use function and task analysis.

(4) Identify HECs.

(5) Review HECs to determine HEDs.

b. Assess the HEDs.

c. Validate and verify each design improvement.

d. Submit to NRC a report outlining all HEDs significant to safety, proposed control room changes, and justification for safety-related HEDs to be left uncorrected or partially corrected. The summary report will only outline the safety-related changes.

6.4 Instrument Needs. During the conduct of CRDR surveys at the plant CRs, team members should have access to the following instruments, calibrated in accordance with manufacturer's specifications, with ancillary equipment:

a. Photometers with illuminance sensors for footcandle measurement and luminance sensors for footlambert measurement.

b. Sound level meters and octave analyzers to measure noise/sound pressure levels in weighted networks and in octave bands.

c. Cameras equipped for providing color photography of CR panels, work stations, and work areas, including access thereto.

d. Environmental instruments, including: thermometers (temperature gradients); sling psychrometer with conversion charts for dry, wet bulb readings (percent humidity); alnor velometer, liquid-filled manometer, or hot-wire anemometer (airflow rates).

6.5 Training of CRDR Teams. Under supervision of the CRDR coordinator and the human factors specialist of each CRDR team, team members will receive specialized training. Team members must attend a short course of instruction in HFE. Specialized training will relate to topics selected from the documents and resources cited in subsection 6.1, and other topics determined by the CRDR coordinator. CRDR team members are responsible for their continuing on-job training and updating in their specialties. They are also responsible for applying their expertise in coordinating and integrating the CRDR effort with related efforts (see section 4.0).

6.6 Control Room Task Analysis.

6.6.1 Purpose and Scope. The purpose of the task analysis effort as it relates to the control room design review is to evaluate operation aspects of the control room design. Included in this evaluation are control/display relationships, availability of information, visual and communication links, and traffic patterns.

6.6.2 Methodology. The CRDR task analysis activity starts with the plant-specific symptom-oriented Emergency Operation Instructions (EOIs) after they have been validated by the utility. Appropriate NUC PR personnel will develop a task worksheet (appendix E-10) for each EOI which will contain the following information:

- Task - Specific step in the EOI.

- Device/location - Primary control used by the operator to perform the task and the location of that control.

- Associated devices/location - Any devices used in conjunction with the primary control to perform the task or to provide feedback and the location of that device.

- Assistance/communication - Any assistance used by the operator or any communication necessary.

The first two items will be developed before the walk-through/talk-through. The remaining information will be completed during the walk-through/talk-through.

These completed worksheets will be used to answer the following:

- Required instrument and controls.

- The identified instruments and controls are appropriately located in the control room and are suitable for decision making.

- Communication and assistance needs.

Those pieces of information plus any comments made on the worksheet will be used to identify HECs which will be assessed in accordance with subsection 8.0.

In order to prepare the survey team for this activity, a brief presentation will be given for each event sequence to be used in the walk-through/talk-through. The presentation will cover the following areas:

- Initiating event/symptoms.

- Significance of each event sequence.

- Affected process systems.

- Operating crew actions to recover from the event.

6.7 Additional Analysis. The CRDR team will evaluate the need to perform additional analysis (walk-through/talk-through review, task, system, or functional analysis) for other control room activities as necessary. The team will decide the most appropriate method for evaluating potential problem areas. The team will consider the operating history of the plant and the information gained from the questionnaires and operator interviews in determining if additional analysis is necessary and to what extent additional analysis will be performed.

6.7.1 Criteria for Selection of Items for Additional Analysis.

6.7.1.1 Normal, Abnormal, and Emergency Operations. Additional analysis shall be performed for any control room activities identified by the operator interviews/questionnaires as potential problem areas.

NOTE

For lengthy activities identified, it is acceptable to limit the additional analysis to potential problem areas only.

6.7.2 Procedure for Additional Analysis (AA). The additional analysis will typically be done by walk-through/talk-through review. It is important to remember that the purpose of the walk-throughs/talk-throughs is not to evaluate the procedure or the operator, but the control room. The purpose of AA is to determine if the given layout of controls and displays enables the operator to effectively operate the plant in a given situation. The AA will be performed as talk-throughs. The primary source of information is the operator and no particular attempt will be made to evaluate time requirements. (Obvious time problems, however, will be considered.) The number of team members should be limited to two or three: one given primary responsibility for questioning the operator and one taking notes. Prior to starting, the purpose and methods of the walk-through/talk-through should be discussed with the operator so that he knows what to expect. The operator talks through the identified activity describing the actions taken, what to look for, and where the problem may arise. Attention should be given to control/display relationship and for indications or controls not available in the control room. The results obtained from each walk-through/talk-through will be summarized and any identified HEC documented.

7.0 IN-PLANT CONDUCT OF CRDR

7.1 Duration. TVA training simulators will be used to limit the amount of time required by the CRDR teams at the plant. The onsite phase (plant survey) of the CRDR is estimated to take two weeks.

7.2 Review of Operating Experience. CRDR team members will review documented operating experience of the plant(s). Operating experience documents include:

a. Historical records, such as SCRAM and Trip Reports.

b. Licensee Event Reports (LERs).

c. Earlier preliminary CRDR reports.

d. CRDR reports of other TVA plants.

e. Generic CRDR reports of the industry.

Also included in the review of operating experience are the questionnaire and interview surveys of plant operating personnel. (See subsections 7.3.16 and 7.3.17.)

7.3 Control Room Survey. Arrival onsite of the CRDR multidiscipline team signifies transition from the preparation stage to the applications stage of the team effort. With their specialized training and technical area expertise, the team is ready to identify HECs during the applications stage, that is, the onsite control room survey.

7.3.1 Transition of Multidiscipline Team Focus. The onsite control room survey will focus on:

a. HE acceptability of the MCR and ACR.

b. Evaluation of operator task performance capabilities.

The first day the CRDR team is onsite will be devoted mostly to administrative matters, such as plant ingress/egress, security, site and MCR layout, plant procedures and protocol, introduction to plant personnel, and assignment of workplaces for the CRDR team members. Daily schedules will be detailed. The advanced-planning, tentative assignment of in-plant duties to CRDR team members will be confirmed or revised as appropriate.

7.3.2 Use of Checklists. The checklists, appendix A, consist of nine sections with each section containing its own table of contents. The checklists are abstracts of HE principles as they apply to the CR. Early in the CRDR preparation phase, individual team members will be given responsibility for specific checklists. Early assignment of checklist responsibilities will facilitate their effective use during the onsite survey.

Checklist use during the survey requires the CRDR team member to select one of three HE compliance choices (alternatives): "Not Applicable (N/A)," "Yes," or "No." The team member's decision has prime significance relative to the identification of a potential HED. A "Yes" signifies compliance with HFE

principles. A "No" signifies a HEC. Team members will use the "Reference/Comment" space for two purposes: (a) to decide "Yes" or "No" whether they believe a checklist item is safety-related and (b) to record unusual aspects of the checklist item. The post-survey assessment work session will establish the appropriate status of HECs and confirm whether or not an HED is safety-related. On completion of a checklist, the CRDR team member will complete, as appropriate, one or more HEC worksheets (Appendix E). At the end of each onsite survey workday, the team member will give his completed checklist(s) and corresponding HEC worksheets to the CRDR leader. The collected checklists and worksheets are principal agenda items in the post-survey assessment work sessions. HED report forms will be completed during the post-survey HEC assessment work sessions and used to document CRDR team findings and recommendations for corrective action.

The CRDR team members will use the checklists during the onsite survey, under escort as required. The CRDR team member will use the checklist without interfering in control room operations.

7.3.3 Inventory. The control room task analysis activity (refer to subsection 6.6) applies to the emergency operating instructions (EOIs),and the associated inventory will identify only controls and displays associated with the EOIs. In addition, during the operating experience review (refer to subsection 7.2), any unnecessary or distracting controls and displays identified by operating personnel will be analyzed by the review team to assess their status.

7.3.4 Photography. Photography service will be provided to the CRDR team. The photo service task will be to get high quality color prints of all panels, operator desks, worktables, and access paths. The prints will be used during the preparation, onsite survey, assessment, and implementation of the HED action plan. CRDR team members may wish to document potential HECs with photos during the onsite survey. Photo service will include identification and logging of all negatives and prints for CRDR team use following the onsite survey. In addition, photos may be used to document specific HEDs resulting from the review team's assessment of identified HECs.

7.3.5 Lighting Survey. Illuminance levels (footcandles) will be measured at each operator desk and worktable, and at each benchboard and vertical panel. Sensors should be placed at the geometric center of each operator desk and worktable. Some deviation from the geometric center placement may be necessary so the survey can proceed without interfering with ongoing operator activities. At benchboards, sensor placements will be at the geometric center and approximately 36 inches above the floor. For a vertical panel, sensor placements will be at the panel vertical center line approximately 60 inches above the floor.

Luminance levels (footlamberts) must be measured at each vertical panel. The probe will be aimed at one or more panel areas, from the operator's eye position and at a height of 60 inches above the floor. Lighting (illuminance) and luminance survey forms are identified in subsection 7.3.20.

7.3.6 Sound and Noise Survey. Sound and noise levels will be measured at each operator desk and worktable. Microphone positions will be at the approximate ear positions of the 5th percentile female operator, 50th percentile male operator, and 95th percentile male operator, for both sitting and standing working positions. Measurements will be taken in three response or "weighted" networks, "A," "B," and "C," and in the octave bands centered at 16 through 16,000 Hz. Measurements may also be taken at other locations throughout the CR at the discretion of the CRDR team leader.

The acoustical test data worksheet is identified in subsection 7.3.19.

7.3.7 Workspace Survey. The TVA control room workspace design is based on the concept of effective use of instruments, controls, and computer/communications terminals by the operator. This concept means that adequate space be provided to allow the operator unencumbered command of all instruments, controls, terminals, and work tasks. Work tasks are performed sitting, standing, and walking; panel-to-panel, and work-station-to-work-station.

Additional space makes it easier to communicate and work with other operators, supervisors, and other personnel, such as maintenance personnel, who have the need and authorization for

control room access. The workspace survey has the following components: general layout, work station design, multiunit control rooms, emergency equipment, and environment. Specific checklist items are in Appendix A, paragraphs 1.1.1 through 1.5.8.

7.3.8 Communications Survey. The communications survey has the following components: voice communications and auditory signal systems. Checklist items are in Appendix A, paragraphs 2.1.1 through 2.2.7.

7.3.9 Alarm Systems Survey. The alarm systems survey has the following components: general system characteristics, auditory alert subsystem, visual alarm subsystems, and operator response subsystem. Checklist items are in Appendix A, paragraphs 3.1.1 through 3.4.3.

7.3.10 Controls Survey. The controls survey has the following components: selection, design principles, pushbutton specifications, rotary specification, and other specifications. Checklist items are in Appendix A, paragraphs 4.1.1 through 4.5.4.

7.3.11 Visual Displays Survey. The visual displays survey has the following components: principles of display, meters, light indicators, graphic recorders, and miscellaneous display types. Checklist items are in Appendix A, paragraphs 5.1.1 through 5.5.2.

7.3.12 Labels and Location Aids Survey. The labels and location aids survey has the following components: labeling principles, location, content, lettering, use and control of temporary labels, and location aids. Checklist items are in Appendix A, paragraphs 6.1.1 through 6.6.3.

7.3.13 Process Computers Survey. The process computers survey has the following components: access, CRT displays, and printers. Checklist items are in Appendix A, paragraphs 7.1.1 through 7.3.3.

7.3.14 Control-Display Integration Survey. The control-display integration survey has the following components: basic relationships, groups, and dynamic relationships. Checklist items are in Appendix A, paragraphs 8.1.1 through 8.3.2.

7.3.15 Panel Layout Survey. The panel layout survey has the following components: general panel layout, layout arrangement factors, and specific panel layout design. Checklist items are in Appendix A, paragraphs 9.1.1 through 9.3.3.

7.3.16 Control Room Operations Questionnaire. The questionnaire is Appendix C. Appendix C explains the purpose of the questionnaire and the instructions for its use by operators and other questionnaire respondents. The questionnaire items are taken from NUREG 0700.

The questionnaire will be sent to each RO, SRO, shift supervisor, and shift engineer at each TVA nuclear plant, early enough to allow completion and return to the review team technical leader prior to starting the onsite survey. The questionnaire will be treated as confidential and anonymous. However, any respondent is invited to advise the CRDR of his name and telephone number if he wants to amplify or clarify his responses or comments; in this case, a CRDR team member will contact the respondent during the plant onsite survey.

7.3.17 Operator Interviews. CRDR team members will use the structured interview format in Appendix D to interview operators. Appendix D explains to the interviewer the purpose and method of the interview. [The structure and content of the interview were derived from EPRI NP-309 (reference 11.1.1).] CRDR team members conducting interviews will be given prior training, following the guidelines of T. J. Bouchard in the Handbook of Industrial and Organizational Psychology (reference 11.4.1).

Operators selected or volunteering to be interviewed during the survey will be given a copy of Appendix D prior to the interview. Protocol for selecting operator interviewees or arranging for volunteer operator interviewees will be agenda items for plant visits prior to arrival onsite of the CRDR team. The biographical data form, Appendix D, will be completed by the interviewee and made available to the interviewer prior to the interview.

7.3.18 New Instrumentation Survey. This survey addresses new instrumentation installed in compliance with R.G.1.47, and R.G.1.97, or installed for other reasons. The survey will address operator acceptance, operator training, integration with other instruments and controls, and completeness of operating instructions. Pertinent checklists from appendix A will be used.

7.3.19 Walk-Through/Talk-Through of Task Analysis. The task worksheets developed during the analysis of the EOIs will be used by the CRDR team to monitor the walk-through/talk-through of the CR by a licensed operator for the following reasons:

a. Reveal the organization of operator tasks.

b. Establish operator's information needs.

c. Identify input, output, and throughput of operator actions.

d. Support HE evaluation of CR equipment.

7.3.20 Worksheets and Data Forms. The worksheets and data forms for use by the CRDR team members are assembled in appendix E. Their titles, proposed use, and disposition are shown in Table 2.

TABLE 2

Appendix Page	Title	Use By CRDR Team	Disposition
E-1	Operator Interview/ Questionnaire Biographic/Anthropometric Data Worksheet	Mailed to respondents. Biographic/Anthropometric Data Worksheet may be completed by CRDR team member or operator when used during operator interview.	Statistical summary in final report.
E-2	Human Engineering Concern Worksheet	During preparatory phase and during survey.	Possible input into HED report form (E-3).

TABLE 2 (Continued)

Appendix Page	Title	Use By CRDR Team	Disposition
E-3	HED Report No.	Principal record of HED. Prepared during the post-survey assessment phase.	Input into HED Summary report. V&V agenda. Final report.
E-4	Lighting Survey Worksheet	Data collection during CR lighting survey.	Data reduction and presentation. V&V. Final report.
E-5	Luminance Survey Worksheet	Data collection during CR luminance survey.	Data reduction and presentation. V&V. Final report.
E-6	Acoustical Test Data Worksheet	Data collection during CR sound/noise survey.	Data reduction and presentation. V&V. Final report.
E-7	Air Velocity Survey Record	During CR survey.	Data reduction and presentation. V&V. Final report.
E-8	Humidity/Temperature Record	During CR survey.	Data reduction and presentation. V&V. Final report.

TABLE 2 (Continued)

Appendix Page	Title	Use By CRDR Team	Disposition
E-9	Photo Log	During CR survey.	Data reduction and presentation. V&V. Final report.
E-10	Task Worksheet	During walk-through/ talk-through	Possible input into HED record.

8.0 ASSESSMENT OF THE CONTROL ROOM DESIGN REVIEW

8.1 Assessment Phase.

8.1.1 Assessment of HECs. The assessment phase begins upon completion of the onsite survey. Early in the assessment phase, the CRDR Team will study each HEC to determine whether it should be redesignated into HED status. The redesignation of a HEC to HED status is a determination/evaluation as to the accuracy of the HEC as to not complying with human engineering criteria used in the control room survey as it applies to the plant design. Thereupon, the CRDR progresses into the evaluation of the significance of all HEDS.

8.1.2 Assessment of HEDs.

a. Objectives. The objectives of this phase of the CRDR are as follows:

- Evaluate and document the significance of the HEDs defined in the previous phases of the CRDR.

- Recommend changes to the control room, procedures, operator training, or any combination thereof to resolve these HEDS.

b. Evaluation Criteria. HEDs found during the control room survey, the operating experience review, and the task analysis will be evaluated according to their potential to adversely affect operation.

8.1.3 Description. In general, it is expected that three broad classes of HEDs will be identified during the review phase: HEDs with a safety significance to emergency response, HEDs whose correction would contribute to improved normal operation, and HEDs whose correction would provide a general human factors

enhancement of the control room. A categorization method will be developed to facilitate the retrieval of HEDs from the data base in a format consistent with the manner in which HED assessment will be performed.

In addition, assessment criteria and guidelines will be developed to aid the Review Team in the analysis and prioritization of HEDs. The guidelines will be designed to assess the potential for causing or contributing to operating crew error, the plant safety consequences of such error, operator performance and efficiency, overall plant operability, costs, and feasibility among other areas of concern.

Some HEDs may be corrected by simple surface enhancement techniques, such as changing labels, or reorganizing procedures, adding demarcation lines or mimic lines, etc. Correction of other HEDs may require more extensive measures. If it is determined that the correction must involve movement, modification, or addition/deletion or controls and/or displays, then these corrections will be evaluated with other alternatives and with consideration of how the corrections will impact the existing control room (consistency and compatibility), plant availability, and operator training, performance, and procedures. In some cases, training may be the only technique needed to resolve HEDs. Proposed modifications may be made on the mockups or simulators and evaluated with procedures to determine their overall effectiveness. Experienced operators will be used to evaluate alternative approaches. Established human factors guidelines will also be used to review proposed modifications.

8.2 Data Reduction and Analyses.

8.2.1 Human Engineering Discrepancies (HEDs). On completion of the onsite survey, and review of HECs and HEDs, pertinent worksheets and supporting documentation will be assembled to enable a two-way categorization of HEDs: safety-related and non-safety-related.

The nature and urgency of each HED correction/ modification will be addressed in post-survey work sessions of the CRDR team.

8.2.2 Control Room Task Analysis. The result of the CR task analysis will be studied in the post-survey work sessions of the CRDR team.

All other data, assembled both in the preparation phase and the survey phase, reduced, and interpreted, serve the two basic questions on validation and verification (V&V).

8.2.3 Photo Log and Photo Records. The photo log and photo records will support and document the HED record. Available to the CRDR for their post-survey work sessions, they will also serve as "Before" records in the modification-of-HEDs process.

8.2.4 Lighting and Luminance Surveys Data. The lighting (illuminance) and luminance survey data will be reduced and presented in table format, to facilitate estimation of compliance with the guidance of NUREG 0700 and the criteria of the Illuminating Engineering Society of North America.

8.2.5 Sound and Noise Survey Data. The sound and noise survey data will be reduced and presented in table format, to assist the CRDR team in their post-survey work sessions. The data will be studied with reference to the guidance of NUREG 0700 and the criteria of germane professional engineering societies.

8.2.6 Data From Checklists. Data derived from completed checklists relate to subsections 7.3.2 through 7.3.15, and 7.3.18. The data will be reduced in similar fashion and presented in suitable format for evaluation by the CRDR team in their post-survey work sessions. The CRDR team evaluation will be based on HE principles and criteria, NUREG 0700 guidance, experience and proven practices of the power industry, and the guidance and standards of germane professional engineering societies.

8.2.7 Control Room Operations Questionnaire Data. Questionnaire returns will be read promptly after receipt by the CRDR team or designated team member. Most of the returns should be received and read prior to arrival of the CRDR team onsite for the survey. These early returns and readings should allow the CRDR team to focus their survey efforts on potential HEDs. The questionnaire responses will be statistically summarized and presented for evaluation by the CRDR in their post-survey work sessions.

8.2.8 Operator Interview Data. Similar to the operator questionnaire returns, the operator interview data will be statistically summarized and presented for evaluation by the CRDR team. All operator responses and individual comments and suggestions will be presented to the CRDR.

8.2.9 New Instrumentation Data. New instrumentation operator-use data, and operator-anecdotal information acquired during the survey by CRDR team members, will be presented to and evaluated by the CRDR team during their post-survey work sessions.

8.3 Recommendations. The post-survey work sessions of the CRDR team will evaluate the HEDs for their impact on safe and productive nuclear power plant operations. The HEDs will be categorized

for precedence and priority of correction. An action plan will be designed and proposed. For each HED, the plan will detail a recommended solution, and when appropriate, one or more alternative solutions, with corresponding priority and materials schedules. For any HED not recommended or scheduled for modification or correction, justification must be given. Each proposed solution will be assessed for its effectiveness in correcting the specific HED, and for its near- and long-term potential impact on other CR systems, subsystems, instrumentation, components, or procedures. For HEDs that do not involve an improvement in emergency response or do not involve a significant safety issue, a cost/benefit analysis may be required to support control room modifications.

8.4 Verification and Validation. Each modification implemented as a result of a HED will be analyzed in the TVA training simulator facilities, and in mockup studies for their verification and validation. Verification and validation are long-term processes involving continued testing and analyses (reference 11.1.6). Mockup studies will be in accordance with EN DES Design Guide G18.1.12 (reference 11.2.2). In addition, an USQD must be performed to document that the proposed design improvements can be introduced into the CR without increased risk, or a temporary or permanent reduction in safety.

9.0 IMPLEMENTATION PHASE

9.1 Objective. The primary objective of the Implementation Phase is to implement modifications, procedures, and training as necessary to resolve significant HEDs that may affect plant safety and operability.

9.2 Description. Modifications required to resolve significant HEDs will be implemented through the existing station modification process.

Since the modification process for all selected HEDs may take a considerable amount of time for implementation, the implementation and follow-up activities will rely upon normal organizations both at the plant and in NUC PR and EN DES. Therefore, it becomes obvious that the HED(s) and the resulting modification request(s) must be very explicit as to what is to be done. An organized transition will be made between the Review Team and the line organizations in order to assure effective implementation of the results of the CRDR. The CRDR team management and the appropriate line organization will be responsible for defining and implementing this transition.

9.3 Future Control Room Modifications. In order to ensure adequate human factors considerations for all modifications that are considered after the CRDR team has completed its activities, the line organizations responsible for modifications will implement the necessary criteria and procedures to evaluate the human factors aspects of all future control room modifications. Proposed solutions should be reviewed by those responsible for operating the plant.

9.4 Action Plan. A proposed HED action plan will be prepared by the CRDR team for each plant and submitted through appropriate TVA line organizations for review and use. The HED action plan will include as a minimum the following:

- Identification of each HED.

- Corrective action for each HED.

- Priority assignment for HEDs.

The appropriate TVA line organization will be responsible for final disposition of the CRDR team HED action plan. The disposition of the HED action plan will be provided to the CRDR team for information and use.

9.5 Documentation. All documents and worksheets will be filed. The HEC and HED forms will be controlled by revision level and date of changes. The HECs will be maintained in a separate file from the HEDs.

10.0 SUMMARY REPORT

The appropriate TVA line organization will utilize the HED action plan so as to develop a summary report for each plant outlining proposed control room changes. Subsection 6.3.d defines the requirement for the summary report.

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2. EN DES Design Guide E18.1.12, "Human Factors Engineering in Control Console, Cabinet, and Panel Layout."

3. EN DES Design Guide E18.1.13, "Human Factors Engineering in Alarm Systems."

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5. EN DES Design Guide E18.1.15, "Human Factors Engineering in Operator/Computer Interface and Dialog.

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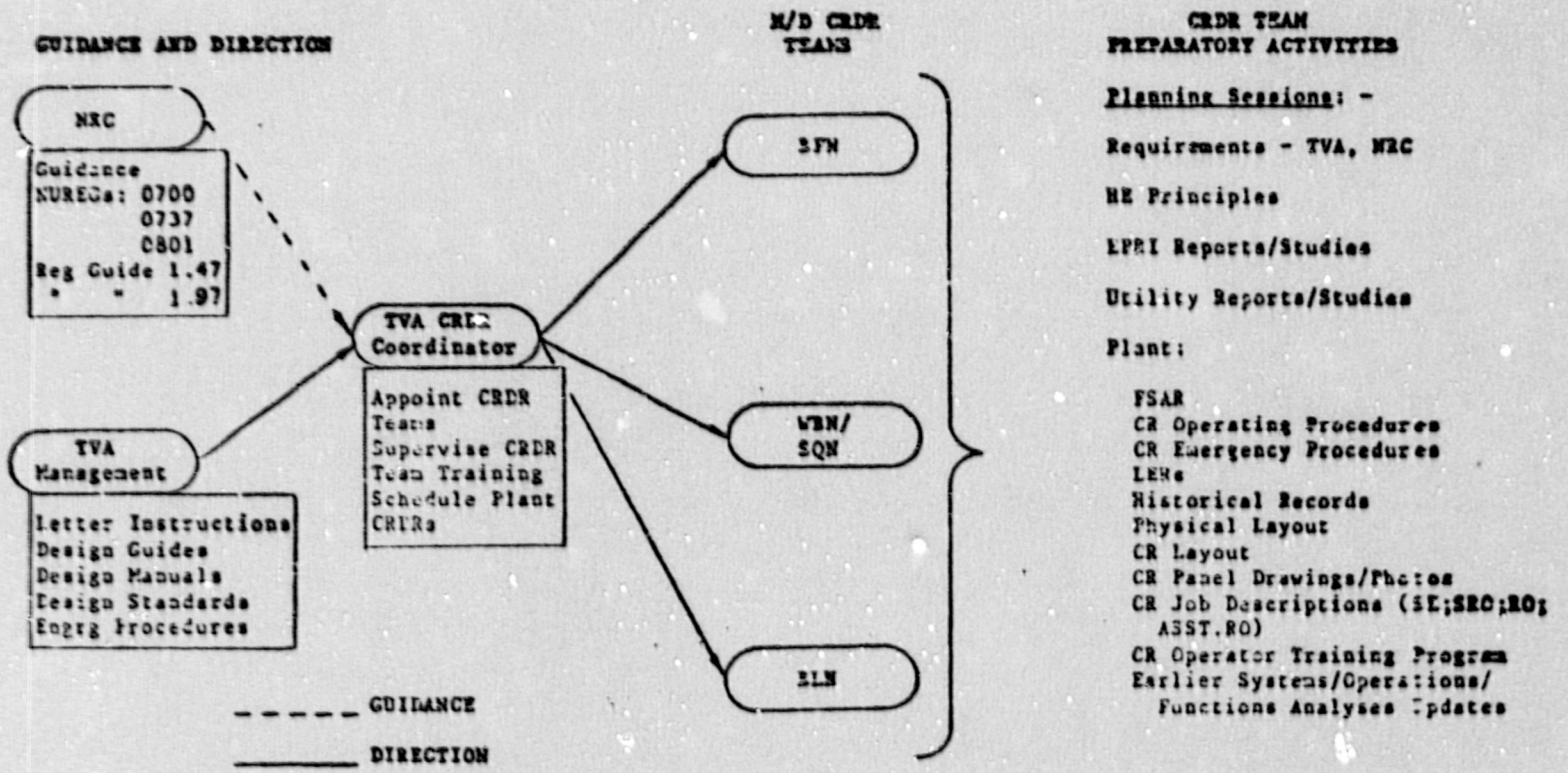


Figure 1. GUIDANCE, DIRECTION, AND ACTIVITIES OF CONTROL ROOM DESIGN REVIEW PREPARATION

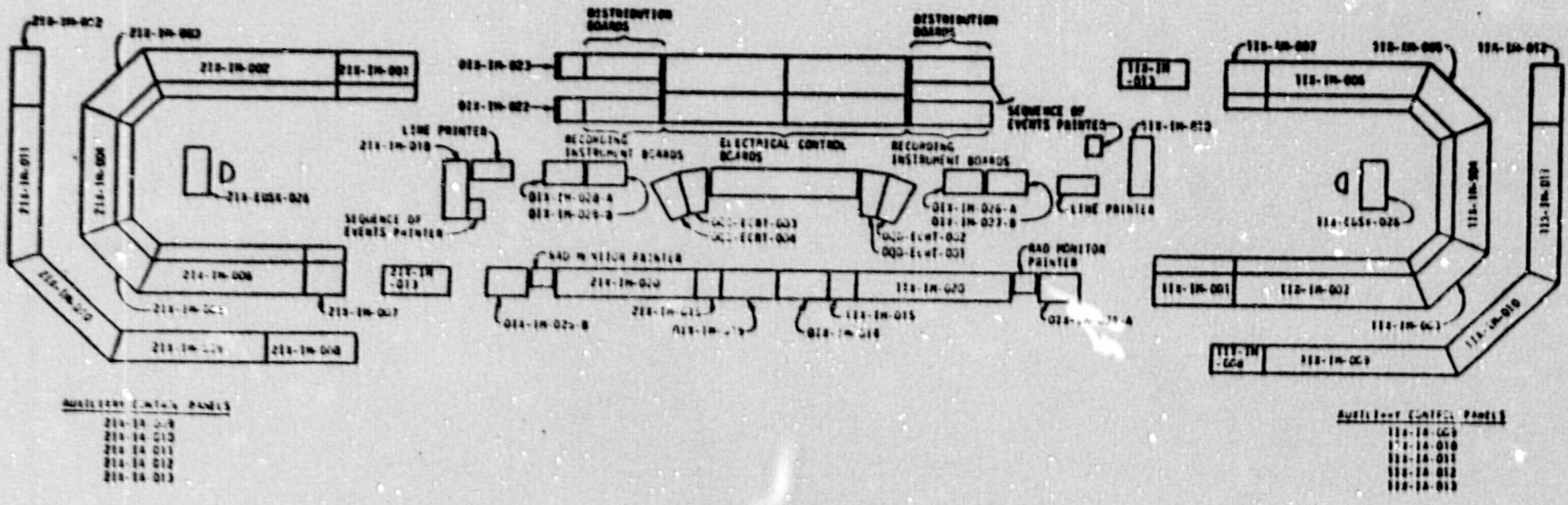


FIGURE 2
BELLEFONTE NUCLEAR PLANT CONTROL
ROOM ARRANGEMENT UNITS 1 & 2

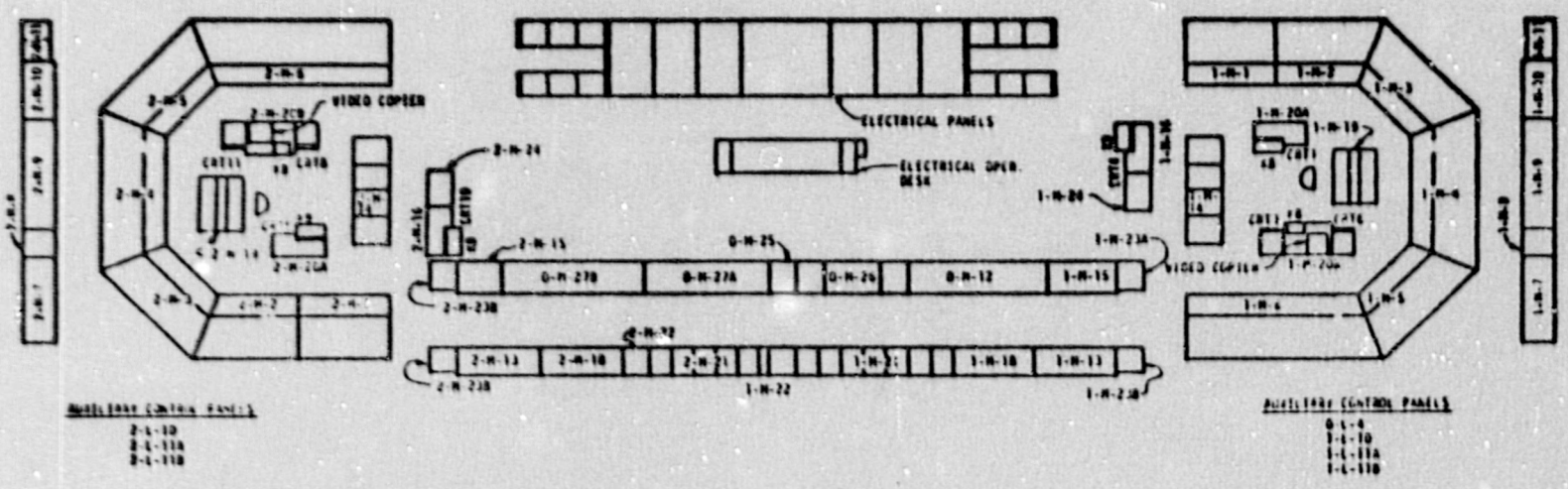


Figure 3
WATTS BAR NUCLEAR PLANT CONTROL ROOM ARRANGEMENT - UNITS 1 & 2

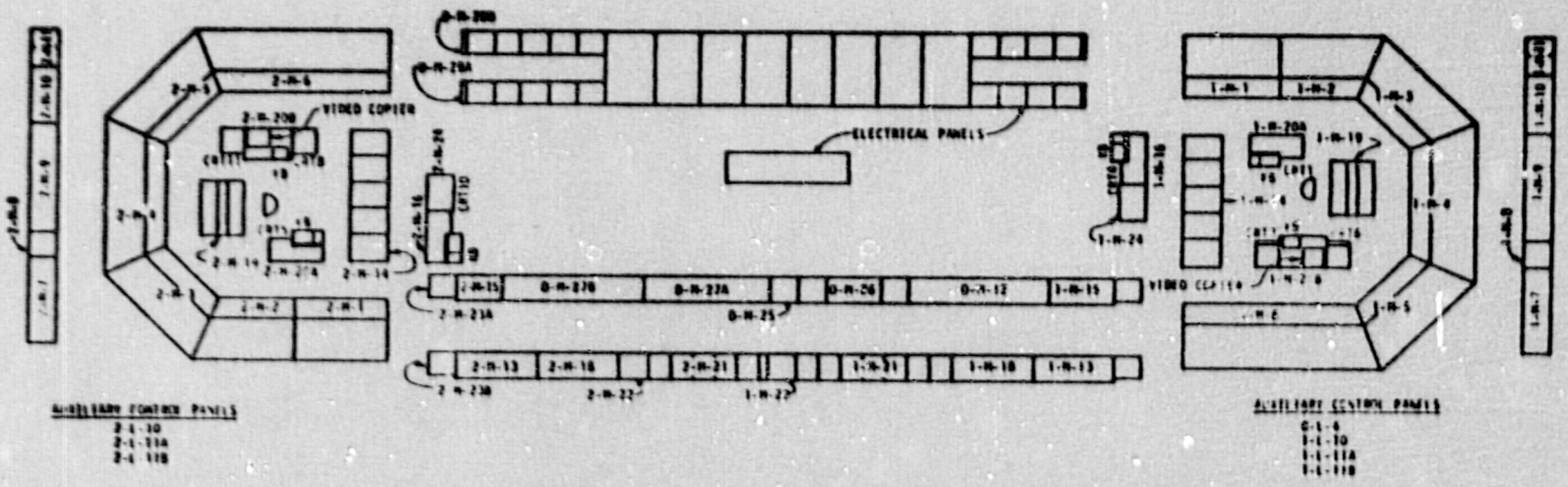


Figure 4
SEQUOYAH NUCLEAR PLANT CONTROL ROOM ARRANGEMENT - UNITS 1 & 2

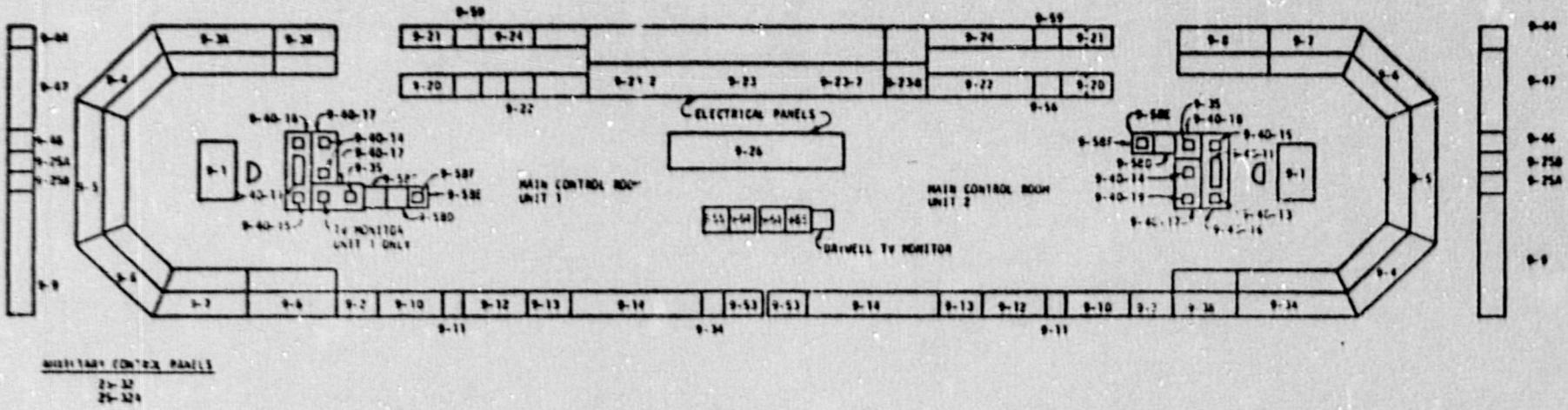
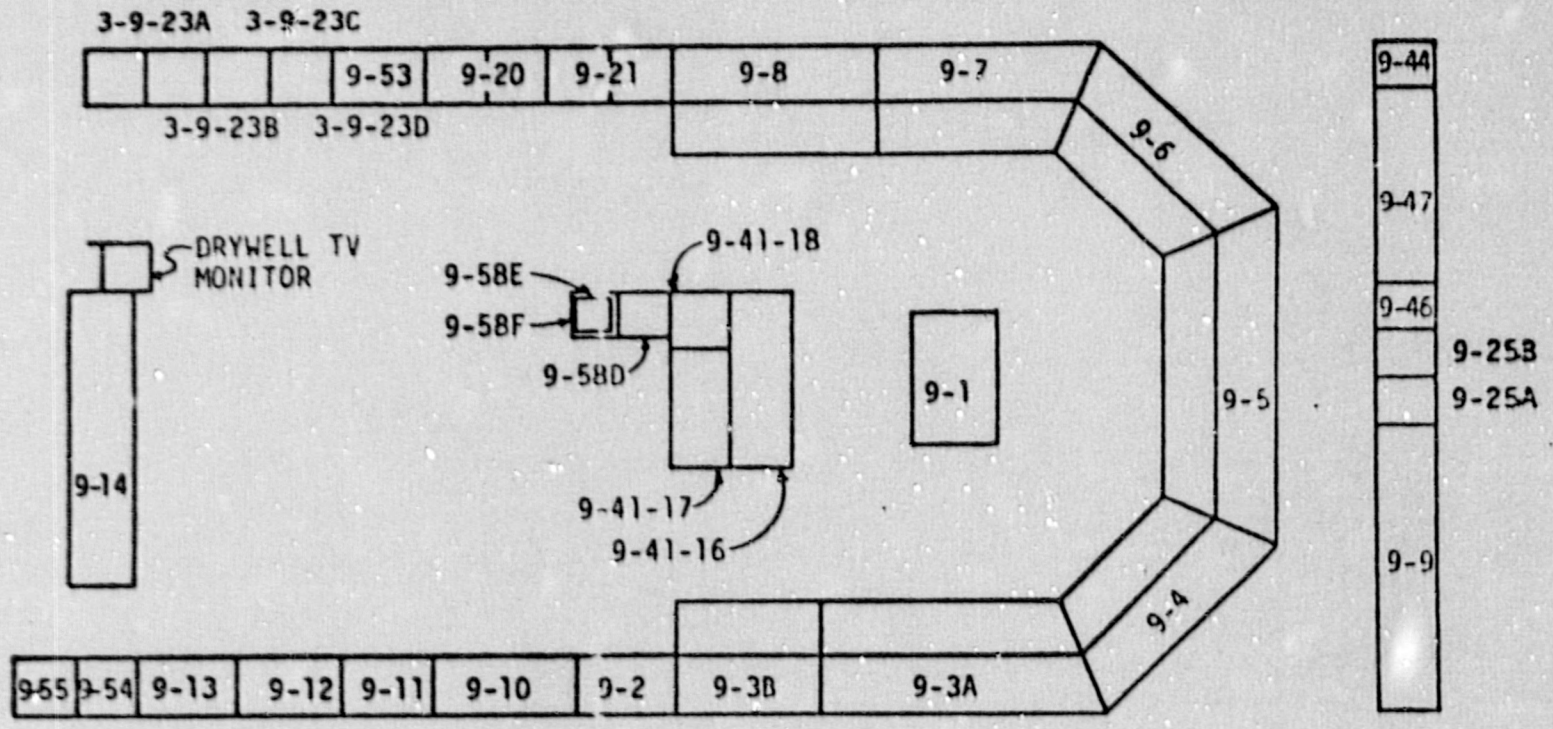


Figure 5
BROWNS FERRY NUCLEAR PLANT CONTROL ROOM ARRANGEMENT - UNITS 1 & 2



AUXILIARY CONTROL PANELS

25-32
25-32A

Figure 6
BROWNS FERRY NUCLLAR PLANT CONTROL ROOM ARRANGEMENT - UNIT 3

Appendix A

Control Room Human Engineering Checklists

APPENDIX A

1.0 CONTROL ROOM WORKSPACE

NOTE

THE CHECKLIST (APPENDIX A) MAY BE REPLACED BY A CHECKLIST DEVELOPED BY THE NUCLEAR UTILITY TASK ACTION COMMITTEE ON CONTROL ROOM DESIGN REVIEW WHEN RELEASED.

CONTROL ROOM HUMAN ENGINEERING CHECKLISTS

Appendix A contains detailed checklists to be used by the CRDR team members in preparing for the CRDR and during the in-plant conduct of the CRDR. The checklists were derived from NUREG-0700. A few revisions and references were made based on TVA EN DES Design Guides (reference 11.2), MIL-STD 1472C (reference 11.3.2), EPRI NP-1918-SR (reference 11.1.4), and ASHRAE (reference 11.4.8). Instructions for using the checklists are given in subsection 7.3.2 of this Program Plan.

The checklists are divided into nine sections as listed below:

1.0 Control Room Workspace
2.0 Communications
3.0 Alarm Systems
4.0 Controls
5.0 Visual Displays
6.0 Labels and Location Aids
7.0 Process Computers
8.0 Control-Display Integration
9.0 Panel Layout

CONTROL ROOM WORKSPACE 1.0
GENERAL LAYOUT 1.1

GUIDELINE

COMPLIANCE CHECKLIST

N/A	Yes	No	Reference/Comment

1.1.1 ACCESSIBILITY OF INSTRUMENTATION/ EQUIPMENT

a. **PRESENT IN THE CONTROL ROOM**—Control room instrumentation and equipment should include all controls and displays needed for (1) detection of abnormal conditions, and (2) bringing the plant to a safe shutdown condition.

b. **ARRANGED TO FACILITATE COVERAGE**—Operators should not have to leave the primary operating area (see Exhibit 1-1) to attend to control room instrumentation on back panels during operational sequences in which continuous monitoring or the timing of control actions may be critical.

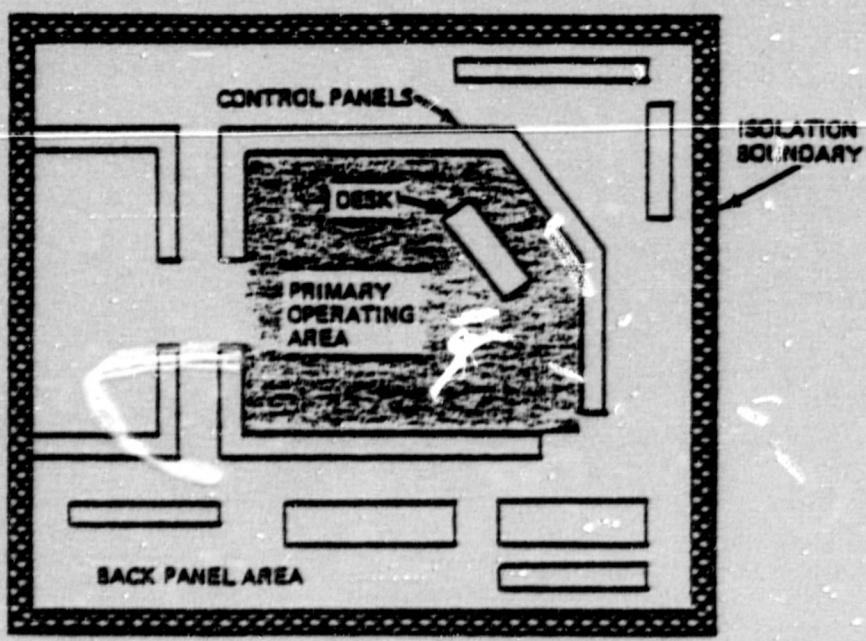


Exhibit 1-1. The primary operating area is physically arranged such that it can be visually accessed from a central point within that area.

GUIDELINE

COMPLIANCE CHECKLIST

N/A	Yes	No	Reference/Comment

1.1.2 CONSISTENCY OF MANNING WITH EQUIPMENT LAYOUT

a. COVERAGE—Control room manning and task assignments should ensure complete and timely coverage of controls, displays, and other equipment required during all modes of operation.

CONTROL ROOM WORKSPACE 1.0
GENERAL LAYOUT 1.1

GUIDELINE

COMPLIANCE CHECKLIST

N/A	Yes	No	Reference/Comment

1.1.3 FURNITURE AND EQUIPMENT LAYOUT

Placement and spacing of equipment depends on control room configuration, manning, and other design features. Thus, guidelines are stated in terms of minimum spacing considerations for common equipment arrangements and use situations. Maintenance and testing of equipment has not been considered, and may require larger clearances than the minimums suggested.

a. VIEWING—Desks and consoles placed in the primary operating area should permit operators at those desks and consoles full view of all control and display panels (including annunciator panels) in the primary operating area (see Exhibit 1-2).

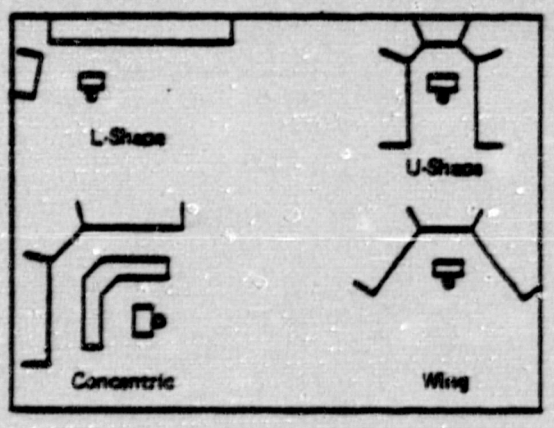


Exhibit 1-2. Control board configurations and desk placements that facilitate sight and voice contact.

1.1.3 FURNITURE AND EQUIPMENT LAYOUT (Cont'd)

COMPLIANCE CHECKLIST

N/A	Yes	No	Reference/Comment

b. OPERATOR ACCESS

(1) Operators should be able to get to any work station without having to overcome obstacles such as tripping hazards, poorly positioned filing cabinets or storage racks, maintenance equipment, etc.

c. CIRCULATION PATTERNS

(1) The control room arrangement should facilitate efficient unobstructed movement and communication.

COMPLIANCE CHECKLIST

N/A	Yes	No	Reference/Comment

1.1.3 FURNITURE AND EQUIPMENT LAYOUT (Cont'd)

d. OPERATOR MANEUVERING SPACE – Between the back (operator's position) of desk/consoles and any surface or fixed object behind the operator, adequate space should be allowed for the operator to get into and out of a chair freely or to turn in the chair to view the equipment behind.

(1) A minimum separation of 36 inches from the back of any desk to any opposing surface is suggested as the minimum (see Exhibit 1-3). A greater separation is preferable.

(2) Lateral space for a seated operator should be no less than 30 inches (see Exhibit 1-3). Greater latitude is preferable.

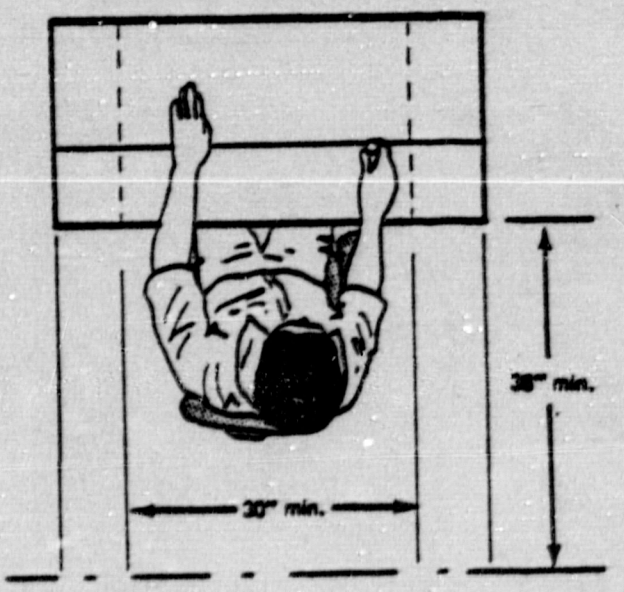


Exhibit 1-3. Spacing of equipment to accommodate seated operators.

1.1.3 FURNITURE AND EQUIPMENT LAYOUT (Cont'd)

e. **EQUIPMENT-TO-OPPOSING-SURFACE DISTANCE**—Enough space should be allowed so that personnel can perform all required tasks. The space should accommodate kneeling and bending, simultaneous work by more than one operator, and simultaneous performance of operational and maintenance tasks as may be required. Recommended minimum separations are illustrated in Exhibit 1-4.

(1) A minimum separation of 50 inches is recommended between a single row of equipment/panel and a wall or other opposing surface.

(2) A minimum separation of 50 inches is also recommended between two rows of facing equipment if both rows are worked by a single operator.

COMPLIANCE CHECKLIST

N/A	Yes	No	Reference/Comment

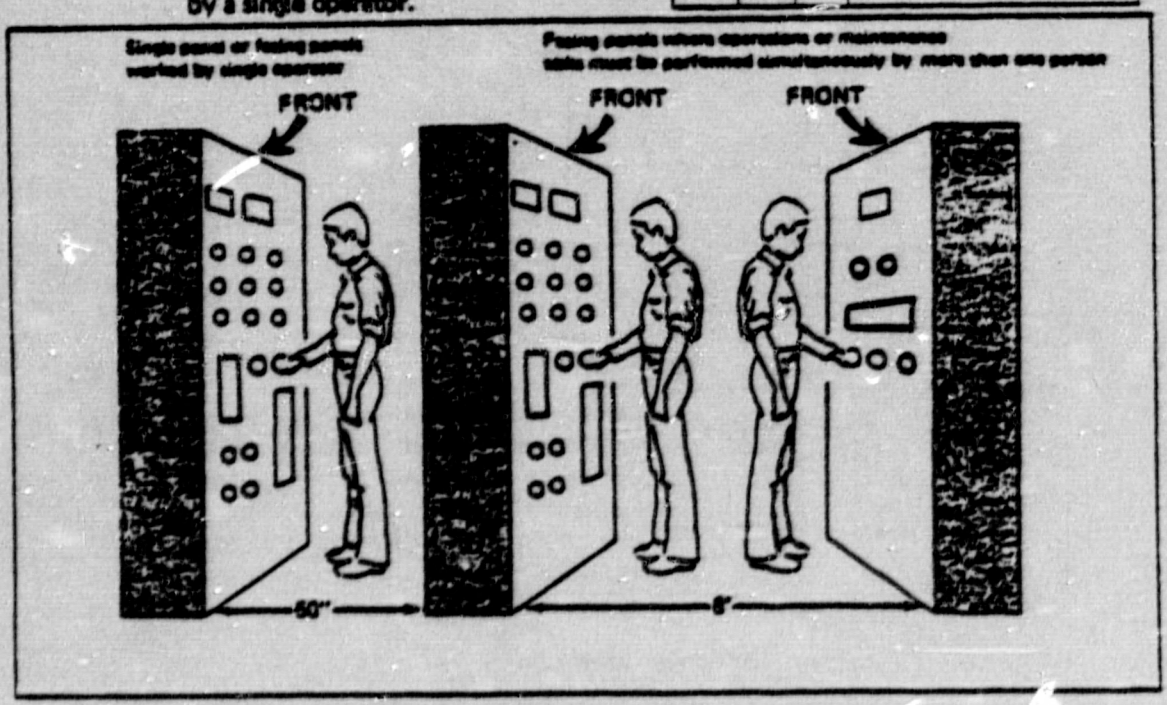


Exhibit 1-4. Equipment-to-equipment distances. Single operator and more-than-one-operator spaces.

COMPLIANCE CHECKLIST

N/A	Yes	No	Reference/Comment

1.1.3 FURNITURE AND EQUIPMENT LAYOUT (Cont'd)

e. EQUIPMENT-TO-OPPOSING-SURFACE DISTANCE (Cont'd)

(3) A minimum separation of 8 feet is recommended between opposing rows of equipment where more than one person must work simultaneously on operational or maintenance tasks and kneeling, bending, or use of test equipment may be necessary.

f OPENINGS--Panels should be laid out and maintained, and equipment enclosures designed, so that there are no unguarded openings through which unwanted objects can be introduced.